DOCUMENT RESUME

ED 229 226 SE 041 426

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TITLE A Synthesis of Findings on Sex Differences in Science Education Research. Final Report.
INSTITUTION Illinois Univ., Urbana.
SPONS AGENCY National Science Foundation, Washington, D.C.
REPORT NO NSF/SED-83001
PUB DATE Jan 83
GRANT NSF-SED-80-07857
NOTE 23p.
PUB TYPE Reports - Research/Technical (143)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Academic Achievement; *Elementary School Science; Elementary Secondary Education; Science Education; Science Instruction; *Secondary School Science; *Sex Differences; Socioeconomic Status; Student Characteristics; *Student Motivation
IDENTIFIERS *Meta Analysis; National Science Foundation; *Science Education Research

ABSTRACT

A meta-analysis of science education literature was undertaken to determine the magnitude and direction of sex differences in school age boys'/girls' motivational orientations and science achievement. A comprehensive review of journal articles/reports, large-scale national/international studies, and standardized testing procedures appearing in the literature since 1965 provided 207 comparisons for motivation and 406 comparisons for science achievement. Results indicate that sex differences in motivation and achievement are smaller than generally assumed, but they do occur, and, with few exceptions, tend to favor males. On the whole, sex differences were larger on achievement measures than on motivation measures. In addition, sex differences appear to be greater in the United States than in other countries and are greater for children in upper than in lower socio-economic status levels. While girls verbally supported the notion that science is "not just for boys," boys were more inclined to engage in science-related activities. Therewith, it appears that engaging in science-related activities and other extra-school experiences may play a critical role in creating sex differences. Nevertheless, school intervention should be fostered, such intervention focusing on science instruction during the pre-adolescent period, the state during which sex differences in orientation and science achievement seem to change. (Author/JN)

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NSF/SED-83001

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ED229226

A Synthesis of Findings on Sex Differences in Science Education Research

Final Report: NSF SED 80-07857

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Marjorie Steinkamp, Co-Principal Investigator

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January, 1983

SE041426

Overview

Self-evidently it is and has been a major concern that women are underrepresented in the scientific community. The reason for this state of affairs is unclear and the topic has more often been the subject of heated discussion than systematic fact gathering. Throughout, educators have been concerned that, unintentionally, the schools may play a major role in determining this state of affairs. Perhaps the way school science is presented, taught or promoted may be at the very heart of the emergence of gender differences in science achievement. The validity of such a fear is by no means self-evident and this uncertainty regarding what the factual situation is, or may be, provided the essential impetus for the project described in this Final Report. Studies on this point are available but heretofore they have existed as a scattered assortment of items, yielding a not-too-coherent picture of the state of affairs so far as gender differences in science achievement are concerned. The purpose of this project was, so to speak, to set the record straight. To this end, a comprehensive research synthesis was conducted in which the reality of gender differences in school-science achievement could be specified, analyzed, and to some small degree, explicated. Gender differences in science achievement clearly do emerge in the school years. The differences are small but persistently evident. Their origins are not always clear but the project suggests possible avenues of action that may lead to an understanding of why these differences exist and suggest what can be done about them.

Background and Objectives

That women are underrepresented in professional, scientific, and technical communities is a disturbing and undisputed fact. Doubtless, there are a variety of antecedents to this state of affairs. Important among these is the possibility that school instruction in science may be a major cause. Given this possibility, there are three broad and complementary questions that must be addressed in this regard:

1) Are gender differences, in fact, evident in elementary school achievement?

2) If gender differences are evident, what is their nature?

3) What, finally, is their origin?

Individual research reports vary in their certainty regarding the answers to these questions and there is currently no satisfactory integrative review of the literature which provides a summary of the state of knowledge on this topic. A review of the research literature which provides a comparison of boys' and girls' performance on science-related measures--together with information on factors which contribute to sex differences--might facilitate the development of policies, theory and classroom techniques more conducive to long-term achievement in science for females. The purpose of this project was to provide such a systematic and comprehensive review of the available data.

As a matter of record, few systematic and comprehensive reviews have been undertaken in this area of inquiry. Those that have been undertaken have frequently failed to make maximal use of the information which is available on gender differences. For example, search procedures have often lacked the systematic rigor necessary for

comprehensive examination of gender differences. The typical library search covers only those reports whose titles and abstracts provide a clue that the issue of gender differences was addressed in this study. The present project employed more thorough search procedures in an attempt to locate any study or report in which the sample was described in terms of boys' and girls' performance on science-related measures. The inclusion of such studies not only increased the size of the data base but also provided a closer approximation to the natural setting since variables controlled or manipulated on a study were tailored to issues other than those associated with gender. Earlier efforts to accumulate information on sex differences in science have been narrow in another sense; they apparently searched only a smaller portion of the available sources. The present project included not only refereed journal articles, chapters from books, dissertations, and Educational Resources Information Center (ERIC) documents, but also included data from standardized testing procedures and large-scale national and international studies. Inclusion of reports which use varied samples and diverse testing conditions can provide more realistically representative data on the subject at hand.

Overall, then, the review was extensive and comprehensive. Within the parameters established at the outset, a comprehensive search was initiated to locate gender information on 1) school-age children, 2) reported in the English language, and 3) published between the years 1965 and 1981. As will soon be evident in the description of outcomes and results, the analyses were equally extensive and comprehensive. Thus, a variety of statistical

procedures were employed and, wherever possible, multivariate procedures were used to maximize the interpretative possibilities.

Project Activities

Data Search

A first activity in research synthesis is to identify the studies to be synthesized. Given the parameters noted above, the search focused first on refereed journal articles, books, unpublished reports and dissertations. To locate these reports, computer searches of five library data bases were conducted: Psychological Abstract (PSYCH), Educational Research Resources Information Center (ERIC), Social Science Index (SSCI), Comprehensive Dissertation Index (CDI), and Smithsonian Science Information (SMIE), Also, comprehensive reviews of tables of contents and page-by-page scanning of books and journals were undertaken. All volumes of the two major journals in science education--Journal of Research in Science Teaching and Science Education were scanned for the years 1965 through early 1981. All volumes of Sex Roles and Psychology of Women were scanned for the entire period of their publication. All volumes of School Science and Mathematics (1969-1981) were individually examined. Also, the most recent five years of the following journals were examined: Developmental Psychology, Journal of Educational Psychology, Child Development, Human Development, and Child Psychiatry and Human Development. Dissertation Abstracts were located through listings in International Dissertation Abstracts.

It should be especially noted that our research was considerably broader than that defined in the initial proposal--and broader than that of typical quantitative reviews--in that special studies and standardized test results were incorporated into the data base to be integrated. Also, search procedures which were more intensive than those typically employed in quantitative reviews were applied. The additional effort taken here is summarized in three paragraphs below.

Additional data: special studies. In addition to journal articles, dissertations, books, and technical reports typically uncovered in a library search, national and international studies were examined for data on sex differences related to science learning. A comprehensive collection of publications from the National Assessment of Educational Progres (NAEP), Project Talent, International Association for the Evaluation of Educational Achievement (IEP), and the summary volume Girls and Science were combed for sex comparisons. Not only were data from these sources based on large samples from developed and developing countries across the globe, but data were often conveniently reported by categories highly relevant to the goals of the project.

Additional data: standardized tests. Manuals accompanying standardized tests were searched and found to provide valuable data on relative achievement of females and males in science. In order to gather test scores, the extensive test library collection located in the University of Illinois library was perused. The library collection contains approximately 6,000 tests and accompanying manuals, of which approximately 270 deal with some aspect of science. The 1974 edition of Buros' Tests in Print, science section, was also

examined for titles of science test manuals which might be searched for data on sex differences in science. The Educational Testing Service (ETS) provided an extensive set of mean and standard deviation scores from thousands of high school juniors and seniors in biology, chemistry, and physics for the years under study. Other test services and corporations provided in-house computer outputs and copies of test manuals.

Intensification of search procedures. The nature of the project required search procedures which were more intensive than the computer scanning of major data bases. It became apparent at the outset that computer retrieval by itself was inadequate to the particular task at hand. Too frequently in this project, neither the title nor the article abstract could be counted on to indicate whether or not sex-related differences were addressed in the study. This meant that in order to ensure a comprehensive search, every report suspected of addressing the topic of sex differences or suspected of dealing with the issue peripherally had to be visually scanned, page by page. Some of the most detailed data in the study were retrieved visually from studies addressing a variety of unrelated topics within education and psychology.

All in all, then, one can see that a comprehensive search was initated and conducted. Further details in this regard are contained in the papers and reports stemming from this project (see later).

Resultant Sample

The research yielded a grand total of 613 effect sizes. Moreover, it should be kept in mind that underlying these effect sizes were responses from more than 14 million students from twenty

countries around the world. The results determined in the project stem from data that can only be considered massive in nature, number and scope--and perhaps also, important.

Coding

Following usual procedures, a coding scheme was developed and articles, studies, etc, were analyzed and assessed in accord with this scheme. A copy of the categories coded appears in Table 1 (appended). An expanded description of coding procedures employed is available from the investigators.

Summary of Project Outcomes

Subsequent to coding of the data, effect sizes were subjected to a series of analyses. Results of these analyses and the general interpretations of the outcome of the project as a whole may be reviewed as revolving around four major subprojects or tasks, each of which is more fully reflected in an extended paper[1], but each of which is also briefly described below.

TASK 1: Direction and Magnitude of Sex Differences in Motivation and Achievement in Science

It became apparent in the early stages of the project that many sources which reported achievement scores for males and females also reported data on motivational variables known to impinge on the learning of science. Because these data were highly relevant to the broad goals of the project, the decision was made--in consultation with project consultants--to expand the scope of the study by

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[1] Preliminary drafts of these papers have been sent earlier and reprints will be sent as they become available.

retrieving and integrating studies containing data on motivation as well as data on achievement. In addition to providing information on these variables separately, this approach has the advantage of yielding information on how motivation and achievement interacted with a variety of situational and psychological contexts.

Following a comprehensive review of the literature containing comparisons between boys and girls and some measure of motivation in science/and or some measure of achievement in science, findings were transformed into a common metric--an effect size--and analyzed meta-analytically. Drawn from articles and reports, large-scale national and international studies, and standardized test procedures, the data base provided a total of 207 effect sizes for motivation and 406 effect sizes for achievement in science.

It was found that sex differences in both motivation and achievement are smaller than generally assumed, but they do occur, and with few exceptions, they tend to favor males. The literature sources contained information on 25 variables suspected of impinging on motivation and science. These were analyzed in depth and related to the direction of magnitude of sex differences in motivational orientation. Of special interest is the finding that when asked outright, girls more than boys object to stereotypic labels for science subjects but when it comes to identifying personally with science, engaging in science activities, or selecting careers in science, they continue to act in traditional ways. Girls' attitudes toward science appear to differ from their attitudes toward careers in science. The underrepresentation of females in science classes and programs of study noted by others is in accord with this conclusion.

A paper describing this sub-project and its results in greater

detail has been written. A copy of this paper is available for dissemination through the authors and has been submitted for publication. A draft of this paper has already been sent to NSF and reprints of this publication version will be sent when available.

TASK 2: Relationships among Affect, Ability and Achievement

A large number of studies provided correlational data among affect, ability, and achievement variables but could not be fitted into the main analyses of gender differences because they did not provide data for the calculation of effect sizes. The purpose of activity under Task 2 was to provide a synthesis of these studies. This opened a new avenue of inquiry which served to complement and supplement the findings tapped earlier in the analysis of effect sizes.

The literature search yielded 67 articles or papers which reported correlations among affect, ability, and achievement in science and between each of these variables and gender. 255 correlations were derived from these studies and formed the data base for these projects. These correlations were synthesized quantitatively with a view to determining the size and direction of relationship as well as the degree to which the relationships were modified by gender, levels in school, and content within science.

As expected, it was found that positive attitudes toward science are associated with achievement. However, the relationship is weaker than might be expected. Overall, students tend to do well in science if they like the subject. However, how well they do depends more on their ability than on their liking for science. The data suggest that boys achieve slightly better than girls in science and that they tend

to possess more cognitive ability. In some content areas within science, boys demonstrate more positive affect than do girls. In other content areas, such as biology and chemistry, the reverse is true. Again, a paper reporting these reports in detail is available for general dissemination. A draft version was sent to NSF earlier and reprints will be sent when they become available.

TASK 3: Sex Differences in Science-Related Cognitive Ability

In the early stages of the project it was necessary to set limits on the scope for the review in order that it could be completed on time and with care. Designated as primary focus of the inquiry were studies which addressed specific content areas within science, such as chemistry, physics or geology. Attracting our attention throughout the project, however, were studies which dealt not with science per se, but with cognitive variables such as conservation, visual and spatial ability, and formal reasoning. Without question, these abilities play a seminal role in determining student' attitudes and levels of achievement in the social sciences. These issues sparked the interest of a graduate student on our staff who made the topic the focus of her dissertation research.

Essentially, this subproject occasioned a literature search somewhat distinct from the one which had formed the basis for the other analyses. This search yielded 70 U.S. and foreign studies which met the essential criteria for meta-analysis and which also conformed to the overall project.

The results showed small but rather consistent sex differences in favor of males. While girls exhibited a slight superiority in clasification and seriation, boys slightly, but consistently, outpeformed girls in such cognitive operations as conversation,

spatial visualization, proportional reasoning, disembedding, and field articulation. The overall magnitude of effect size (ES = .32), however, is not large. The analyses of variance and regression analyses indicated, further, that such differences depended somewhat on the cognitive domain. Also, the results showed that gender differences varied depending on response mode. When the response mode was public (e.g., oral rather than written), making role definition more salient, gender differences were likely to be greater.

The dissertation reporting these results is available through the University Microfilms Service. (A copy of the Abstract is appended). Papers based on this dissertation are currently being prepared for publication and will be sent to NSF as they become available.

TASK 4: Interpretation of Results and Policy Development

Each of the sub-projects or tasks involved interpretation in terms of theory, application and even, more broadly, policy. However, the concern with the place of the quantitative findings in the context of educational practice and policy was more than an incidental and isolated concern associated with each set of results. This concern was pursued through regular discussion with staff and consultants. It perhaps was most vigorously pursued in a "summit meeting" of staff and consultants held toward the end of the project.

The results of these efforts are reflected in each of the major project groups. However, these results are also reflected in two theoretical papers and to no small degree in the basic format, thrust, and nature of a forthcoming book edited by Steinkamp and Maehr. The theoretical papers are listed later. A description of the book and its contents is to be found in the following section. While

these sources better reflect the course of our thinking in pursuing this project, several summary statements may nevertheless be in order.

Overall, it was somewhat surprising to learn that gender differences were as small as they were. As small as they may be, however, they are there. And, an important thing to emphasize is that this conclusion is based on data from more than 14 million students in twenty countries. We are not talking about a conclusion that can be taken lightly. Yet, the very smallness of the differences, as well as other factors, may suggest that the school's role in creating or reducing them may not be as large as we might have expected or hoped. Indeed, differences really don't begin to be seen until quite late in school, around pubescence, when society as a whole as much as anything else, emphasizes that two worlds exist for the sexes. This is not meant to suggest that the school should decline responsibility for this state of affairs. After all, the school retains a role in helping the child interpret the world at large; it also plays at least some role in determining the present and future nature of that world. In this regard, it seems clear that the school's efforts are rightly focused on how science is introduced, handled, presented and modeled during the junior high-middle school period. Emphases on senior high science may be important for a variety of reasons but it is not at this level that one can expect to make differences in the achieving orientations of girls. As we see it, the junior high-middle school is a most critical point in the evaluation of differential orientation toward science. Those who must set policy, plan programs, establish curricula--and teach--do well to become aware of this.

But what can be done to improve motivation and learning in science? Unfortunately, the meta-analysis really tells us little because, in the main, research has not really focused directly on this issue. In this regard, however, the two theeoretical papers are of some interest. Basically, these papers sum up what little we know on the topic and suggest theoretical perspectives for the pursuit of further research.

A first paper ("On doing well in science: Why Johnny no longer excels; Why Sarah never did") was presented at the University of Michigan Summer Institute on Learning and Motivation in the Classroom and will be published shortly (see later for details). Building on the research in what has come to be called "achievement theory" Maehr suggests that the "classroom climate" may be particularly important for girls. Classrooms which stress competition and authoritarian control probably are not good for science teaching generally--but there is a strong argument that they may be especially debilitating for girls. In a chapter to be published later this year (see later) Steinkamp proposes that pattern of childhood behaviors--a motivational style--sets the stage for adult achievement in science. Exploratory behaviors are a major ingredient of a style that eventuates in scientific achievement.

So much for what the literature seems to suggest regarding the issues at hand. In many ways, what the literature does <u>not</u> suggest is most interesting. One cannot help but be dismayed by the quality of research associated with science teaching-learning. It is spotty and focused in scope, all too often flawed in method/procedure and, above all, lacking in integration and theory. Perhaps the only integrating theory used to any major extent is that of Piaget and even that is

seldom applied in purity and with consistency. Moreover, it might be questioned whether it is the appropriate theory in most instances. But the point is that serious consideration must be given to the quality of research in this area and research quality is, of course, tied to quality of theory. One might simply repeat the oft-heard phrase: "more research is needed." That may be true. More appropriate, we think, is the admonition that better theory is needed in order that integratable pieces of evidence might be gathered into a coherent picture. It is not that research has not been done; it is that one has difficulty fitting studies into larger conceptual frameworks. In a practial way, this means that research in this area should be more theoretical. We are again reminded of Lewin's oft-quoted admonition that nothing is so practical as good theory.

Products

It is clear that the present project has yielded a number of different results. As one measure of the scope and nature of these results it may be of interest to list and briefly describe the various products of our activities.

Papers Available for Dissemination

Maehr, M. L. On doing well in science: Why Johnny no longer excels; Why Sarah never did.. (In press, draft sent earlier to NSF).

Steinkamp, M. W. Motivational style as a mediator of adult achievement in science. (In press, draft sent earlier to NSF).

Steinkamp, M. W. and Maehr, M. L. Gender differences in motivational orientations toward achievement in school science: A quantitative synthesis. (Submitted for publication, draft sent earlier to NSF; reprints to be sent when available).

Steinkamp, M. W. and Maehr, M. L. Affect, ability, and science achievement: A quantitative synthesis of correlational research. (Submitted for publication, draft sent earlier to NSF; reprints to be sent when available).

Tohidi, N. Sex differences in cognitive performance on Piaget-like tasks: A meta-analysis of findings. Unpublished doctoral dissertation, University of Illinois at Urbana-Champaign, 1982. (Abstract appended; Papers based on this dissertation are being prepared for publication and will be sent when available).

Convention Presentation

Two symposia stemming from this project were presented at the American Educational Research Association meetings in the spring of 1982. In a symposium entitled, "Sex-related differences in science," the empirical findings of the project were presented. Highlighting a second symposium oriented toward methodological issues of meta-analysis was the work of L. V. Hedges from the University of Chicago who discussed "An analogue to the analysis of variance for effect size data." This paper was selected as the outstanding paper within Division D (Measurement and Research Methodology) delivered at the convention.

Seminars, Workshops, and Colloquia

Two colloquia were presented locally, one at the Institute for Child Behavior and Development and the other at the College of Education. These events served as channels for the dissemination of information concerning project implementation and preliminary findings. Also, the findings were presented at a workshop conducted at the University of Chicago. Entitled, "Women in Science," the

workshop was part of a two-day conference on the topic, Women and the University.

Paul Hurd, project consultant, presented a colloquium for the College of Education (and others) at the University of Illinois. This event was funded in part by the Institute for Child Behavior and Development and took place in association with one of the planned meetings of the consultants on the project.

Empirical results and a description of the process of meta-analysis were presented by the Principal Investigator to various groups at the University of Queensland, Brisbane, Australia. The Principal Investigator discussed the findings at the University of Michigan Summer Institute on Learning and Motivation in the Classroom. The paper prepared for that event, "On doing well in science: Why Johnny no longer excels; Why Sarah never did" will appear as a chapter in a volume on motivation and learning in the classoom. That chapter gives a hint to the kinds of theorizing the findings on this project were stimulating.

Twelve-Chapter Volume on Women in Science

Finally, it may be noted that a book has evolved from our work. This book, entitled Women in Science is being published by Johnson Associates, Inc., (JAI Press) and will appear on the market in early 1983. The volume is co-edited by the investigators (Steinkamp and Maehr). The purpose of the book is to provide an overview of problems and perspectives associated with women's achievement in science. The list of contributors, which we believe to be both exceptional and representative of a broad range of approaches to women

in science, includes the following researchers, five of whom also served on our project team:

Helen Astin, Higher Education Research Institute, Inc.
"Academic Scholarship and Its Rewards"

Aimee Grieb and Jack Easley, University of Illinois at Urbana-Champaign
"A Primary School Impediment to Mathematical Equity"

Camilla Benbow and Julian Stanley, Johns Hopkins University
"Gender and the Science Major"

Irene Frieze, University of Pittsburg and
Barbara H. Hanusa, Saint Vincent College
"Women Scientists: Overcoming Barriers"

Lloyd Humphreys, University of Illinois at Urbana-Champaign
"Women with Doctorates in Science and Engineering"

Barbara Kreemer, University of Chicago
"The Meta-Analysis of Gender Differences in Science Learning"

Anne Peterson and Suzanne Kavarell, Michael Reese Medical Center and the University of Chicago
"Patterns of Achievement in Early Adolescence"

Herb Walberg and Margaret E. Zerega, University of Illinois at Chicago Circle
"School Science and Feminity"

Johnathan Cole and Harriet Zuckerman, Columbia University
"The Productivity Puzzle: Persistence and Change in Patterns of Publication of Men and Women Scientists"

Delwyn Harnisch, University of Illinois at Urbana-Champaign
"Females and Mathematics: A Cross-National Comparison"

Marjorie W. Steinkamp, University of Illinois at Urbana-Champaign

"Motivational Style as a Mediator of Adult Achievement in Science"

Table 1

Categories Coded

Characteristics of Study	Characteristics of Instrument
Year of publication	Number of items in test
Source of reference	Type of reliability
Quality of Journal	Reliability index
Sample selection	Type of validity
Sample Size	Source of test
Characteristics of Sample	Individual/group administration
Country of sample	Stimulus mode
Age	Response mode
Ethnicity	Free/structured response
Type of community	Dimension of motivational orientation
Achievement level	Academic Discipline
Socioeconomic status	
Characteristics of School	
Coed/separate	
Instruction type	
Regular class/project	
Public/private	

SEX DIFFERENCES IN COGNITIVE PERFORMANCE ON PIAGET-LIKE TASKS: A META-ANALYSIS OF FINDINGS

Nayereh Essfahlini Tohidi, Ph.D.
Department of Education
University of Illinois at Urbana-Champaign, 1982

A meta-analysis of findings from 70 American and foreign studies comparing school-aged boys' and girls' performances during 1965-81 on Piaget-like tests of cognitive functioning was conducted. The results showed a small but rather consistent sex difference in favor of males. With a slight superiority of girls in classification and seriation, boys slightly but consistently outperformed girls in the cognitive operations such as conservation, spatial visualization, proportional reasoning, disembedding, and field articulation. The overall magnitude of effect size, however, was smaller than that which is generally implied (ES = .32). The means for boys and girls are actually less than half a standard deviation apart. The analyses of variance and regression analyses yielded the following independent variables as significant in explaining the variance in the value of effect size: cognitive domain, response mode, region of country, sample selection, and type of community. Year of publication, type of task and task characteristics in combination with sample selection and sample characteristics explained only 31% of the variance. Problems and concerns related to methodological quality of the synthesized studies are discussed, and some practical implications are offered.

Scientific Collaborators

Principal Investigator	Martin L. Maehr	Professor, Associate Director
Co-Principal Investigator	Marjorie Steinkamp	Senior Specialist
Faculty Associate	John A. Easley	Professor
Faculty Consultant	Herbert J. Walberg	Professor
Faculty Consultant	Paul D. Hurd	Professor
Faculty Consultant	Anne C. Petersen	Professor
Faculty Consultant	Barbara Kremer	Assistant Professor
Research Associate	Anne C. Willig	Graduate Student
Research Associate	Stephen B. Dunbar	Graduate Student
Research Associate	Rosalie Torres	Graduate Student
Research Associate	Katherine Ryan	Graduate Student
Research Associate	Yegin Habteyes	Post-doctoral fellow
Research Associate	Nayereh Tohidi	Graduate Student